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ABSTRACT

The purpose of this study was to develop and validate two hierarchically related measures of concept generalizability. The two concepts were "Insect" and "Animal." The tests were organized in a novel format consisting of three degrees of stimulus complexity. The three degrees of complexity contained sets of pictures of each concept with each set of pictures displaying progressively fewer criterial attributes. The first set contained most immediate criterial attributes while the third set contained the most general. This organization assumed that children attaining the most general exemplars, demonstrating mastery of the concept, should be able to successfully identify exemplars in the two previous set of pictures. It was therefore hypothesized that the tests should conform to Guttman Scalogram requirements and that subjects unable to attain the first or second degree of complexity should also fail the third degree of complexity. The sample consisted of 144 children ranging in age from 6 to 11 years. Results indicated that both measures conform to the Guttman Scalogram requirements and thus constitute valid scales. It was suggested that these tests would enable a more quantitative investigation of concept generalizability.
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A SCALOGRAM ANALYSIS OF TWO MEASURES OF CONCEPT GENERALIZABILITY

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ABSTRACT

The purpose of this study was to develop and validate two hierarchically related measures of concept generalizability. The two concepts were Insect and Animal. The tests were organized in a novel format consisting of three degrees of stimulus complexity. The three degrees of complexity contained sets of pictures of each concept with each set of pictures displaying progressively fewer criterial attributes. The first set contained the most immediate criterial attributes while the third set contained the most general. This organization assumed that children attaining the most general exemplars, demonstrating mastery of the concept, should be able to successfully identify exemplars in the two previous sets of pictures. It was therefore hypothesized that the tests should conform to Guttman Scalogram requirements, subjects unable to attain the first or second degree of complexity, should also fail the third degree of complexity. The sample consisted of 144 children ranging in age from 6 to 11 years. The results indicated that both measures conform to the Guttman Scalogram requirements and thus constitute valid scales. It was suggested that these tests would enable a more quantitative investigation of concept generalizability.

INTRODUCTION

The ability to generalize is considered to be the most important aspect of categorization (Bruner et al., 1956) and concept development (Ausubel, 1965). Vygotsky (1962) equates word meanings with concepts and equates concepts with generalizations. Since word meanings evolve with the child's mental development, this implies the development of a concept becomes increasingly more general. However, the development of this ability in young children is far from clear. For example, studies have reported that generalizing ability is greater in older than younger children (Thompson, 1941), while others (Neimark, 1976; Povey and Hill, 1975), have shown no difference in younger (grade 2) and older (grade 6) children. These inconsistent results are due in part to the methodological problems inherent in the instruments or research designs studying this area.

Tests of ability to generalize have children sort objects or pictures to a given concept label. In general, these tests use pictures of different objects at the same level of generality with the pictures or objects having relatively the same number of criterial attributes available for cateogrization. Since individuals are frequently forced to generalize to instances with a varying number of criterial attributes, the above testing format restricts the amount of information a child can express about a given concept. As a result, the degree to which a child can generalize may be limited more by the investigator's imagination than the child's ability. In this context, Hunt (1976) has argued that a major share of our abysmal ignorance of the details of psychological development during early childhood can be blamed on the nature of our instruments for assessing development. Our ignorance of children's ability to generalize is a case in point, reflecting a lack of instruments and procedures refined enough to provide detailed understanding of this ability.

This study reports on the development and validation of a measure which offers a novel and systematic approach to the quantifying of children's ability to generalize concepts.

STATEMENT OF PURPOSE

The purpose of this study was to develop and validate an instrument which would allow a quantitative assessment of the ability of children to generalize two hierarchically related science concepts. Two instrumetns were developed, one measuring the concept Insect and the other measuring the concept Animal. This paper discusses the developmental rationale and vaidation of both measures using the Guttman Scalogram Analysis procedure. The results of an experimental study using these instruments has been reported elsewhere (Abdullah and Lowell, 1980).

METHODOLOGY

Design

A post-test-only control group design (Design 6), as presented by Campbell and Stanley (1966), was employed in this study. This design is particularly strong in internal validity since random assignment to two groups controls the effects of the extraneous variables that could possibly affect the results of the study.

Sample

The subjects forming the sample were 144 children randomly selected from kindergarten, grade three, and grade five from a school located in St. John's Newfoundland. Forty-eight children (24 boys and 24 girls) were selected from each of the three grades. The subjects in each grade were randomly assigned to control and treatment groups. There were no statistically significant differences ($p = .01$) in age between the treatment and control groups, nor IQ for all groups. Sample parameters are displayed in Table I.

Table 1 Mean Age and IQ of sample

(Age in months)

		Grade											
		Kindergarten				Three				Five			
		Male		Female		Male		Female		Male		Female	
Group	Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Experimental	Age	63.5	2.9	65.1	3.3	104.8	11.1	106.8	3.8	127.5	6.9	124.6	4.6
	IQ	107.8	9.9	104.0	18.6	109.8	14.1	106.3	12.1	105.1	12.1	102.4	7.9
Control	Age	65.8	3.4	64.3	2.8	97.7	2.7	105.8	8.2	127.7	5.5	124.7	9.4
	IQ	104.7	14.0	100.7	7.8	114.8	16.0	104.8	13.3	108.0	12.0	102.9	7.6

INSTRUMENT RATIONALE

The testing format used in this study was designed to allow the child to designate his understanding of a concept by having him choose from a variety of different exemplars and non-exemplars of the concept at varying levels of complexity. Specifically, the instruments were organized using the following format. The child was confronted with three sets of colored pictures representing a concept (either Insect or Animal) at three degrees of increasing stimulus complexity. Stimulus complexity will be referred to here as complexity, complexity being defined as a reduction in the salient number of criterial attributes available to sense perception.

The three degrees of complexity were defined on the basis of the relative number of criterial attributes available and the immediacy of these attributes to the concepts. Thus, pictures of complete representations of instances of a concept would be representative of the First Degree of Complexity. Pictures of a cat or a horse would fall in this category as examples of the concept Animal. These pictures display the greatest number of criterial attributes and are of the greatest immediacy to the concept Animal. Pictures of incomplete representations of instances of a concept would be representative of the Second Degree of Complexity. A fish's tail or the beak of a bird would be examples of incomplete representations of the concept Animal. These representations present a relatively smaller number of criterial attributes and can be considered to be less immediate to the attainment of the concept in question. The child in this case has to infer the concept Bird from the picture of a beak and then generalize from there to the concept Animal.

The Third Degree of Complexity was represented by a product of either an animal or an insect's natural activity. Pictures of a bird's nest or a bee's hive would be examples of this category, for the concept Animal. The picture

of a nest does not present the physical presen-e of a bird but implies the criterial attributes of "birdness". It also can be considered to have the least immediacy while still related to the concept Animal. Such pictures were presumed to be most difficult for the child to recognize and utilize as cues to infer the concept Animal. In this case the child must infer the concept of "birdness" which was only tacitly implied by the presence of a nest and then generalize to the concept Animal. For the purpose of this study, the concept Animal was considered to include all things which are living or which were once living that are not plants and all parts of the bodies of such things as well as the products of their natural activities. Thus, included in the concept Animal would be things like a cat, a bird, a spider or parts of an animal's body, for example, a beak, a frog's hind limb, an alligator's trunk and tail as well as products of the natural activities of animals, such as a spider's web, a bird's nest, a bird's eggs, the moulted skin of a reptile or insect and a beaver's dam. The concept Insect was considered to include all things which are living or were once living, that are not plants whose bodies consist of three parts and which possess three pairs of legs, as well as all parts of their bodies and the products of their natural activities. This includes such things as a house-fly, a dragon-fly, a bee, a butterfly and a beetle. It would also include and insect's wing or legs or part of its abdomen as well as an insect's nest such as a bee's hive or a hornet's nest or an ant's hill.

INSTRUMENT DESIGN

Measure of the ability to generalize the concept Insect

The stimuli used in this instrument consisted of 20 colored pictures cut from nature magazines of insects, insect parts and products of the natural activity of insects. Specifically, there were 10 pictures of instances of the first degree of stimulus complexity and 5 pictures each of the second and third

degrees of stimulus complexity. Examples for each degree of complexity would be a picture of an ant for the first degree of complexity; second degree, a picture of an insect leg; third degree, a picture of a bee hive.

None of these pictures were repeated for the concept Animal. Included were an equal number of non-instances. There were 5 pictures of inanimate objects perceptually similar in general appearances to instances of the concept Insect (e.g., a dragonfly and beetle made of paper or a metal butterfly, etc.). The instances and non-instances were randomly spaced six to a page in a book of pictures.

Measure of the ability to generalize the concept Animal

There were 52 colored pictures of various animals, animal parts, and products of the natural activity of animals cut from nature magazines. There were 24 pictures of a variety of animals including insects which formed instances of the first degree of stimulus complexity. There were 18 pictures of instances of the second degree of stimulus complexity, and 10 pictures of instances of the third degree of stimulus complexity. Examples for each degree of complexity for the concept Animal would be a picture of a dog for the first degree of complexity, a picture of a bird's beak for the second degree of complexity, and a picture of a beaver dam for the third degree of complexity. Also included in the instrument were an equal number of non-instances. There were 18 pictures of inanimate objects such as a clock, fan, etc., 17 pictures of inanimate objects perceptually similar in general appearance to instances of the concept Animal, such as a reindeer and a hippopotamus made of peanuts, a glass horse, a plastic dog, etc. There were also 17 pictures of plants. The instances and non-instances were rnadomly spaced six to a page to form a book of pictures.

Test Administration

Each child was individually tested on the two instruments measuring the ability to generalize the concepts Insect and Animal. The experimenter said

to the subject, "We are going to play a game with pictures and at the end of the game I am going to give you a prize." The experimenter next said, "I am going to tell you a word and then show you some pictures in this book (showing him the book) then I want you to point to all the pictures in the book that you think go with the word I give you." He was then shown a card 3" x 6" on which the word insect was written in bold type. He was then told, "The first word is Insect." He was asked to name any insects that he knew; this was to ascertain that the subject has some notion of the concept being investigated. Only subjects able to name at least one correct insect were included in the study. As it turned out, all subjects knew at least two insect names. For the control group, the subject was then shown the pictures in the instrument designed to measure the ability to generalize the concept Insect. He was told, "Now point to all the pictures that you think go with the word Insect". His selections were recorded. The subject was not told if his selections were right or wrong.

Half of the subjects were shown the pictures from left to right and half the other way around. The same procedure was repeated using the instrument measuring the ability to generalize the concept Animal.

Treatment

In the case of the treatment group, after the subject had stated one or more examples of the concept Insect or Animal, he was shown an equal number of pictures of exemplars and non-exemplars at each of the three degrees of stimulus complexity for each concept. The positive and negative exemplars were pointed out and the subject was specifically told that the positive instances go with the concept in question. The pictures shown for instruction were not included in the testing instrument.

The subject was then asked to point to all the pictures in the test instrument that he thought 'go' with the concept. His selections were recorded and again he was not told if they were correct.

Scoring

For every correct generalization made form each instance of a concept at each of the three degrees of stimulus complexity, a subject was awarded one point. Thus, the maximum score a subject could obtain for the concept Insect was 20 points and for the concept Animal, 52 points. The score obtained by a subject one each degree of complexity was considered to be a measrue of the subject's ability to generalize a given concept. A composite score obtained by summing up an individual's scores on each degree of complexity would then be an overall measure of the extent to which an individual was able to generalize a concept. This is based on the assumption that the three degrees of complexity have an order of increasing difficulty. Support for this assumption would be provided if the data conformed to the requirements of scaling procedures.

Validity

The instruments used in the used in the study were examined by two science educators and three primary school teachers to establish content validity. The judges rated each picture on a seven point scale as to how representative it was for each of the three dimensions of complexity. Pictures which obtained an average of more than 4.5 were used in the final instruments.

Face Validity

A pilot study was undertaken upon completion of the instruments to establish their face validity. The pilot study served two functions: (1) to determine the appropriate protocol of task presentation for all grade levels, and (2) to determine what problems would be encountered in the administration of the two instruments. Six children from each of the grades kindergarten through grade five were tested over a period of one week.

The investigators were concerned whether the younger children would be able to identify the stimuli as instances of the first, second and third degrees of Complexity. It was found that most children were able to recognize the pictures of the insects and animals. In cases where the children were unsure as to what a particular picture was, the specific name for the instance was supplied. Pictures that could not be recognized by all the children were replaced with more illustrative examples.

The tests were correlated to determine the extent to which they were measuring a similar ability. The correlation between the tests was .53 and highly significant ($p \leq .001$).

Reliability

The reliability of the two instruments was determined by a test-retest method. Two weeks after initial testings eight subjects (4 boys and 4 girls) were randomly selected from each of the three grades for retesting. The results show that the Pearson-Product Moment correlation coefficient between the test-retest performance of these children on the instrument measuring the ability to generalize the concept Insect was 0.88. This value was highly significant ($p \leq .0001$). For the instrument measuring the ability to generalize the concept Animal an $r = .97$ ($p \leq .0001$) was obtained.

Data Analysis

The test results for all 144 subjects were pooled to ensure an adequate sample size for the Guttman Scalogram procedure. Separate Guttman analyses were used for each test, Insect and Animal.

RESULTS

In this study it was assumed that a subject having a good understanding of a given concept should not have difficulty in identifying that concept from instances which displayed abstract attributes, for example, attributes which only implicitly suggested that given concept, such as those represented by the Third Degree of Complexity. He would have even less difficulty inferring a given concept from representatives which displayed some or all the attributes of instances of that concept (e.g., first or second degree of complexity). However, a subject whose concept was not well developed would be expected to experience difficulty in generalizing a concept from instances which only implicitly suggested the concept, such as those represented by the Third Degree of Complexity.

Since both texts are organized to form a scale, individuals successfully passing the Third Degree of Complexity should experience little difficulty in passing the Second and First Degree of Complexity. Conversely, individuals experiencing difficulty with the First Degree of Complexity should progressively experience more difficulty with the subsequent Second and Third Degrees of Complexity. One powerful test to determine the validity of this organization is to subject the test results to a Guttman Scalogram Analysis. If the tests are properly organized, the results of such an analysis should conform to the criteria necessary to form a valid scale as determined by the Guttman procedure.

Guttman scale analysis is a means of analyzing the underlying operating characteristics of three or more items in order to determine if their interrelationships meet several special properties. These properties are as follows: First, the scale must unidimensional, with component items all measuring movement toward or away from the same single underlying object of study. Secondly, the scale must be cumulative so that all the component items are ordered by degree of difficulty, in this study the items of the Third Degree of Complexity being

considered more difficult than the items of the Second Degree of Complexity, which in turn are considered more difficult than those of the First Degree of Complexity. This organization is determined by a statistic called the coefficient of scalability.

Thus, individuals failing items which are less difficult are not expected to pass items which are more difficult. Conversely, individuals passing more difficult items are expected to pass the less difficult ones. Furthermore, each item in a Guttman scale must be ordinal to the degree of having the capacity of being divided at some point into two portions -- pass or fail. The cutting points used in this study were the mean scores on each degree of complexity. The means were used as cutting points because it was felt that more than half of the items correctly indicated an understanding of the concept. Subjects having values equal to or greater than the selected cutting points are considered to have passed and those having values less than the cutting points are considered to have failed the items. If a scale is valid, that is, it is truly unidimensional and cumulative, the coefficient of scalability should be over 0.6 (Nie et al., 1975). An additional statistic which may be used to determine the validity of a scale is the coefficient of reproducibility. Generally a coefficient of reproducibility of around 0.9 is considered to indicate a valid scale (Nie et al., 1975).

The results of the Guttman analysis performed on the data of all 144 subjects used in this study are displayed in Figures 1 and 2. As can be seen, the data conform to the requirements of the Guttman scale. The coefficient of scalability of the items for the concepts Insect and Animal were 0.875 and 0.90, respectively. Although the value of 0.875 is slightly lower than the required value of 0.9 for the coefficient of reproducibility for the concept Insect, considering the difficulty in obtaining coefficients of this magnitude it was considered sufficiently high to represent a valid scale.

	1st Degree of Complexity		2nd Degree of Complexity		3rd Degree of Complexity		
ITEM	0	1	0	1	0	1	
RESP.							TOTAL
	ERR		ERR		ERR		
3	0	70	0	70	0	70	70
		ERR					
2	19	12	9	22	3	28	31
				ERR			
1	17	4	10	11	15	6	21
						ERR	
0	22	0	22	0	22	0	22
SUMS	58	86	41	103	40	104	144
PCTS	40	60	28	72	28	72	
ERRORS	0	16	9	11	18	0	54

n = 144

Statistics:
Coefficient of Reproducibility = 0.875
Minimum Marginal Reproducibility = 0.6782
Percent Improvement = 0.1968
Coefficient of Scalability = 0.6115

Correlation Coefficients:

	3rd Degree of Complexity	2nd Degree of Complexity	1st Degree of Complexity
3rd Degree of Complexity	1.0000	0.8742	0.6795
2nd Degree of Complexity	0.8742	1.0000	0.8336
1st Degree of Complexity	0.6510	0.8365	0.6473
SCALE-ITEM	0.6510	0.8365	0.6473

Division point for 1st Degree of Complexity = 9.30
Division point for 2nd Degree of Complexity = 4.50
Division point for 3rd Degree of Complexity = 3.00

FIGURE 1. A GUTTMAN SCALE ANALYSIS FOR THE INSTRUMENT MEASURING THE ABILITY TO GENERALIZE THE CONCEPT INSECT.

	1st Degree of Complexity		2nd Degree of Complexity		3rd Degree of Complexity		
ITEM	0	1	0	1	0	1	
RESP.							TOTAL
	ERR		ERR		ERR		
	0	48	0	48	0	48	48
	ERR						
	38	7	3	42	4	41	45
			ERR				
	23	4	17	10	14	13	27
					ERR		
	24	0	24	0	24	0	24
SUMS	85	59	44	100	42	102	144
PCTS	59	41	31	69	29	71	
ERRORS	0	11	3	10	18	0	42

n = 144

Statistics:

Coefficient of Reproducibility = 0.9028
Minimum Marginal Reproducibility = 0.6644
Percent Improvement = 0.2384
Coefficient of Scalability = 0.7103

Correlation Coefficients:

	3rd Degree of Complexity	2nd Degree of Complexity	1st Degree of Complexity
3rd Degree of Complexity	1.0000	0.7027	0.6190
2nd Degree of Complexity	0.7027	1.0000	0.8298
1st Degree of Complexity	0.6190	0.8298	1.0000
SCALE-ITEM	0.4541	0.6810	0.6306

Division point for 1st Degree of Complexity = 21.5
Division point for 2nd Degree of Complexity = 15.0
Division point for 3rd Degree of Complexity = 4.10

FIGURE 2. A GUTTMAN SCALE ANALYSIS FOR THE INSTRUMENT MEASURING THE ABILITY TO GENERALIZE THE CONCEPT ANIMAL.

As a further index of the validity of the tests the composite score for each test was correlated with age. The results indicate a positive ($r = .57$ for the concept Insect, $r = .50$ for the concept Animal) and highly significant ($p \leq .0001$). Studies have indicated that the ability to generalize is related to age, thus this finding adds further support to the test's validity.

Since the data of this study meet the requirements of the Guttman scale, a total score obtained by summing up the scores obtained by a subject on each of the three degrees of complexity can be considered to be an index of the extent to which the subject could generalize a given concept. This measure can be used to predict or gauge some underlying continuum, for example, the ability to generalize, which is only partially measured by any item, set of items, or variables which are included in the index. In this case, it would be each degree of complexity.

DISCUSSION

The purpose of this study was to develop and validate two instruments which would allow a quantitative assessment of the ability of children to generalize the concepts Insect and Animal. The instrumetns were organized in a novel format consisting of pictures of increasing stimulus complexity. The rationale for this organization was based on the assumption that as a child's concept develops it becomes increasingly more general. As a test of this organization, the test results of 144 children were subjected to a Guttman Scalogram Analysis. The results indicated that both instruments formed valid scales according to the Guttman scaling criteria.

Since the instruments developed constitute valid scales, by employing these tests at various age levels it is possible to assess the development and generality of a particular concept at a given age level. In addition, the relationships between concept generalizability, as measured by these tests, and other variables such as gender, IQ, and developmental level can be systematically explored.

This study demonstrates the feasibility of constructing instruments to quantify concept generalizability. It is important to note, however, that a number obtained from the scales developed here cannot possible represent the full panoply of knowledge a child attached to a particular concept. Nonetheless, the results reported in this study hold promise for more detailed investigations of concept development and generalizability.

Since the child builds and attains new concepts and skills upon those he has already mastered, curricula activities must be sequential and based on a meaningful continuity of learning experiences. Violations of this rule are bound to leave gaps in the child's understanding, and may adversely affect his later progress. What often passes for learning may be sheer rote verbalism without comprehension, in no subject is this more common than science. Therefore, instruction must begin at the stage where the child is capable of understanding and utilizing the basic concepts of the discipline. Clearly, knowledge of the extent to which children are capable of generalizing concepts could very well influence the kinds of concepts children can be taught. This knowledge must be based on sound empirical findings, the work presented here represents a step towards this end.

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